CRITERIA FOR TARGETING YIELDS IN SASKATCHEWAN

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INTRODUCTION

The Saskatchewan Soil Testing Laboratory (SSTL) has been offering nutrient recommendations for soil fertilization based on crop yield increases and the principle of marginal yield return over marginal cost. The latter requires that yield increases are multiplied by a projected price of the various crops and that marginal returns thus derived are divided by the marginal cost, i.e., the cost of fertilizer. An economic return is considered when an extra $1.00 of fertilizer results in $1.50 return in crop yield. Whereas the concept of doing so has been questioned by many, since the economics are based only on fertilizer costs and do not include fixed costs (of which debt load appears to be one of the paramount factors by many farmers), the agronomic data base from which these recommendations are derived are probably a subject of greater concern. This is because much of the database on which current recommendations by SSTL are based on was derived in the late sixties to early seventies and much of the updating and upgrading has been done on an ad hoc and not systematic basis. Furthermore, the database has been developed essentially on three yield increase curves per crop, each corresponding to the Brown, Dark Brown and all the rest soil Zones.

Confronted by the simplicity and the inefficiencies of the current database for SSTL, a number of fundamental questions had to be addressed before a new database and to that effect a new set of recommendations are put in place.

The first question, of course, was whether a yield curve itself is indeed an appropriate vehicle for basing fertilizer recommendations on. Yield curves are limited to the sites where experiments are being carried out and are extrapolated to areas of similar soils and/or environmental conditions. In the current system, all soils, methods of management, personal targets by farmers as well as risk taking for the Black (Thin Black and Thick Black), Grey-Black and Grey soil Zones are described by **one** curve. It would then be logical to attempt to arrive for as many yield curves as possible to describe and address all possible situations in the field. This, needless to say, is an impossible task.

A yield curve, based on conventional statistical techniques, addresses at best **average** situations and as a consequence treats **all** farmers as average as far as their management and fertilizer program are concerned. Most importantly, a number of liberties have been taken by scientists in applying the principle of the **Law of Minimum** especially when multisite and multiyear experiments are conducted. The Law of Minimum or Liebig's Law clearly states that such an exercise (i.e., of deriving a yield curve) can be carried out only when **all other factors except the one under study are at optimum**. Experiments are being carried out with a multitude of factors being at less than optimum and often non-describable levels, yet all results are conveniently placed on **one** yield curve for the description of a phenomenon. Hence , the perception that yield curves from multisite, multiyear experiments appear as the one in Fig. 1 is a gross misconception of reality. When these occur in the literature, they are most often derived from very uniform sites, irrigated sites or sites where similar climatic conditions occur from year to year.

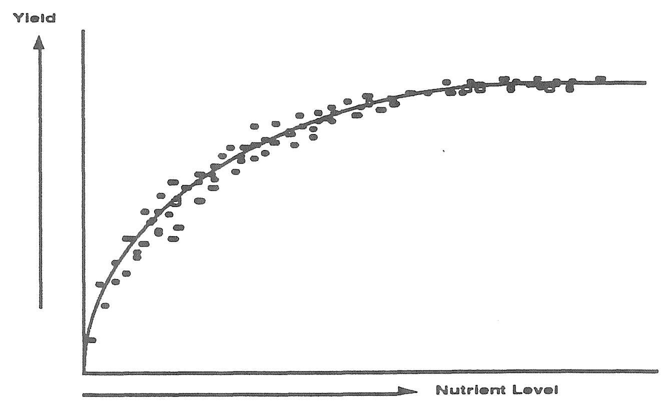

Figure 1. An example of an "ideal" yield curve from a multisite and multiyear experiment.

In reality, a multisite, multiyear yield curve looks more like the one presented in Fig. 2, the main problem now being that farmers A and B or conditions A and B are always treated as farmer or condition C. This liberty with Liebig's Law can be translated as a disservice to the clientele of a soil testing laboratory if not a a misrepresentation of a natural phenomenon. It could, of course, be alleviated if a multitude of curves were to be drawn

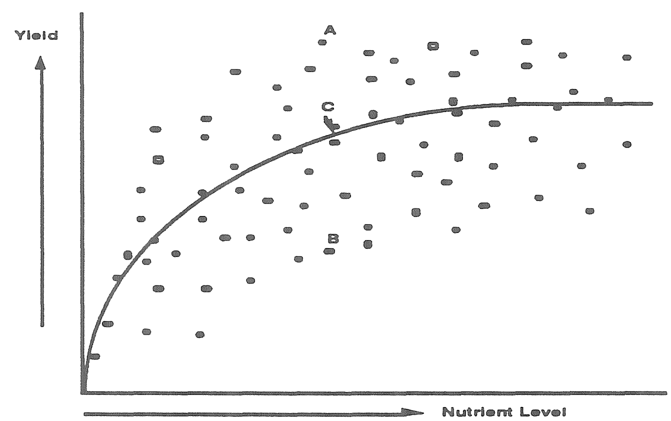

Figure 2. An example of a "realistic" yield curve derived from a multisite and multiyear experiment.

up to represent the variety of conditions under which experiments have been carried out. This process would require that an accurate account of the spatial variability in field is also described. The conditions would probably represent more points than those available on a yield curve!

A more realistic approach would probably be to carry out a boundary analysis of the data (Fig. 3) for which purpose an in depth analysis of the factors causing the various experimental units (points) to fall below the boundary line has to be assessed. This would involve complicated functions and mathematical models if all factors have to be taken into account but can also place more emphasis on mathematics than the natural phenomena. However, an analysis on the basis of **predominant** factors which limit yield is possible.

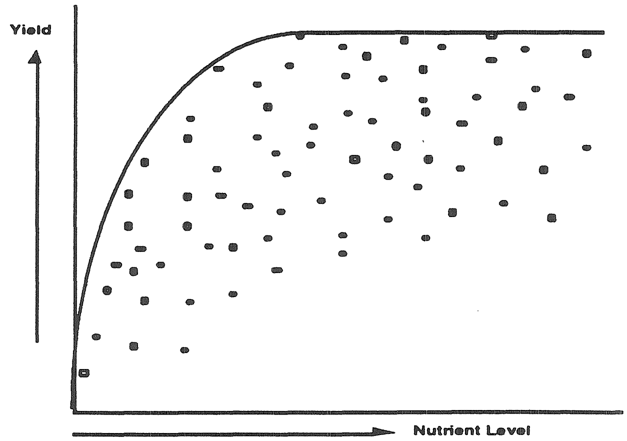

Figure 3. An example of boundary analysis of yield data from multisite and multiyear experiments.

Often in complicated and/or sophisticated models, we tend to forger and/or ignore the limitations of natural systems. As an example, a recently established quality control process at SSTL (Karamanos, 1991a) has pointed out that the "natural" error to be expected from a nitrate-N analysis is ±4.2 lb N/ac. Attempts to refine the process to detect less than 4 lb/ac differences seems illogical.

At the 1988 Soil and Crops Workshop, Dr. F. Selles concluded his presentation (Selles et al., 1988) by saying "tell me how much water a crop will receive and I will give you the yield of the crop". How true this statement has been proven over the last few years looking at crop yields and annual rainfall (Karamanos, 1991b). This realization, long recognized by a scientists, also formed the basis for the development of crop water production functions by Prof. L Henry (Henry, 1990) in order to revise fertilizer (especially nitrogen) recommendations in Saskatchewan. Coupled with this development was also the realization that tools must be offered to farmers to suite their management style and risk taking.

The development of a system for targeting yields in Saskatchewan has also raised a very important issue as to how could a central facility (any Soil Testing Laboratory) address individual farmer needs properly when it processes hundreds of fields on a daily basis during the critical period of decision making by the farmer on his fertilizer program. This question is really independent of the sophistication of the system a central soil testing facility may possess and often is simply limited by the information that can be presented on a soil testing Report. But this issue has to be addressed separately.

THE BASIC SYSTEM FOR TARGETING YIELDS

We will not attempt to reproduce here the system developed by Henry (1990) as copies of the mimeograph can be obtained on request. Rather, we will focus on the main features of the System in its current form.

Climatic Soil Zones

Seven climatic soil zones has been identified, namely, Dry Brown, Brown, Dark Brown, Moist Dark Brown, Black, Moist Black and Grey. A map of these zones will be printed and released in March of 1991.

Development of Yield Equations

Yield equations have been developed on the basis of water use efficiency by wheat, barley and canola at this time (Henry, 1990) from long-term experiments. The yield models are simple linear-plateau type, since this type of model has been shown to provide more realistic fertilizer recommendations (Cerrato and Blackmer, 1990),. The linear portion of the models is reproduced from Henry (1990) for the three major crops in Tables 1 and 2. Adjustments of these curves to fit the seven climatic soil zones are underway.

Table 1. Moisture use-yield equations for barley and wheat (Henry, 1990).

Soil Zone	Barley	Yield (bu/ac) for 10" WU	Wheat	Yield (bu/ac) for 10" WU
Dry Brown	Y = (WU - 2.5) x 5.3	40	Y = (WU - 2.5) x 3.5	26
Brown	Y = (WU - 2.25) x 5.7	44	Y = (WU - 2.25) x 3.75	29
Dark Brown	Y = (WU - 2.0) x 6.0	48	Y = (WU - 2.0) x 4.0	32
Thin Black	Y = (WU -1.75) x 6.4	53	Y = (WU - 1.75) x 4.25	35
Thick/Grey Black	Y = (WU - 1.5) x 6.7	57	Y = (WU - 1.5) x 4.5	38
Grey	Y = (WU - 1.25) x 7.2	63	Y = (WU - 1.25) x 4.75	42

Table 2. Moisture use-yield equations for canola (Henry, 1990).

Soil Zone	Yield equation	Yield (bu/ac) for 10" WU
Dry Brown	Y = (WU - 2.5) x 2.0	15
Brown	Y = (WU - 2.25) x 2.5	20
Dark Brown	Y = (WU - 2.0) x 3.0	24
Thin Black	Y = (WU -1.75) x 3.3	27
Thick/Grey Black	Y = (WU - 1.5) x 3.6	31
Grey	Y = (WU - 1.25) x 4.0	35

Probability of Precipitation

Long-term climatic data have formed the basis for the rainfall probability data presented in Table 3. These data will also form the basis for yield predictions for 25%, 50% and 75% probability of obtaining a certain yield in each climatic soil zone. Table 4 is a reproduction from Henry (1990) but will require revision to be adapted to the seven climatic soil zones delineated after Prof. Henry's original Report.

Fertilizer Recommendations

The system for fertilizer recommendations is still in the process of being developed. It would require the determination of organic matter as a routine analysis by SSTL and will be based on crop removal of nutrients. It is anticipated that the producer will be given a choice to provide his/her own target yield and recommendations along with the probability of obtaining the same will be printed on the Report along with those of target yield for 25%, 50% and 75% probability of precipitation on the basis of either measured spring moisture or a typical value for an area etc. The disadvantage of "averaging" parameters will

Table 3. Probability of precipitation in various soil climatic zones.

Soil Climatic Zone	Probability 25%	50%	75%
		inches	
Dry Brown	7.0	5.6	4.3
Brown	7.5	6.0	4.5
Dark Brown	8.1	6.4	4.8
Moist Dark Brown	8.2	6.5	4.9
Black	8.2	6.8	5.3
Moist Black	8.5	6.8	5.3
Grey	8.8	7.4	5.8

not disappear as, for example, mineralization rates, fertilizer use efficiency and nutrient removal will be based on average values for a set of conditions. However, there will be enough flexibility in the system for modifications.

EXAMPLES USING PUBLISHED RESULTS

Published Reports in the literature of fertility work for which spring soil moisture has been recorded are scarce. An attempt was made to utilize some of the available information from Saskatchewan research to illustrate the predictability of the Basic System. Certain broad assumptions had to be made for each example, since a complete set of the necessary parameters was not always available.

Experiments by Selles et al. (1988)

Spring moisture and May-July precipitation are reported but data are averages of many sites. Only maximum rate of fertilizer was reported, which was not always the one required to arrive at maximum yields. It was assumed for this example that soil organic levels in the site averaged 5% and fertilizer use efficiency was 50%. The average spring soil moisture, May-July precipitation, the estimated spring wheat yields under optimum fertility and the maximum yields obtained by Selles et al. (1988) are given in Table 5. A comparison of the recommendations provided by the current SSTL fertilizer recommendation program, preliminary recommendations for target yields based on 5% organic matter and 2" spring soil moisture and the rates, which would be required to obtain the maximum yields and the corresponding maximum rates reported by Selles et al. (1988) are provided in Table 6. A comparison of target yields sought for each year on the basis of spring soil moistures (Table 5) and the maximum obtained by Selles et al. (1988) is afforded in Table 7.

These comparisons although based on broad assumptions show the benefit of utilizing the new system for nitrogen fertilization of spring wheat and confirm the observation by Selles (personal communication) that the current system tends to over-recommend under dry conditions and under-recommend under moist conditions.

Experiments by van Kessel and Livingston (1989)

A comparison of yield among other parameters is afforded for dryland and irrigated spring wheat grown at Outlook. Again, the organic matter level had to be assumed to be

Table 4. Grain yields predicted by crop water production functions (Henry 1990).

	Yield (bu/acre)											
Soil Zone	Soil water (inches)	Wheat			Soil water (inches)	Barley			Soil water (inches)	Canola		
		25%	50%	75%		25%	50%	75%		25%	50%	75%
Dry Brown	6	35	31	25	6	53	47	37	6	20	18	14
	2	21	17	11	2	32	25	16	2	12	10	6
	0	14	10	4	0	21	15	5	0	8	6	2
Brown	6	43	36	30	6	66	56	46	6	29	24	20
	2	28	22	15	2	43	33	23	2	19	14	10
	0	21	14	8	0	32	21	12	0	14	9	5
Dark Brown	6	46	38	34	6	70	58	50	6	35	29	25
	2	30	22	18	2	46	34	26	2	23	17	13
	0	22	14	10	0	34	22	14	0	17	11	7
Thin Black	6	55	50	41	6	83	75	62	6	43	39	32
	2	38	33	24	2	57	50	37	2	30	26	19
	0	30	24	16	0	44	37	24	0	23	19	12
Thick/Grey Black	6	56	50	44	6	83	75	66	6	45	40	35
	2	38	32	26	2	57	48	39	2	31	26	21
	0	29	23	17	0	44	35	25	0	23	19	14
Grey	6	63	60	50	6	96	90	75	6	53	50	42
	2	44	41	31	2	67	62	46	2	37	34	26
	0	35	31	21	0	53	47	32	0	29	26	18

Table 5. Average climatic data and spring wheat yields for Selles et al. (1988) experiments.

Year	Spring Moisture	May-July Precipitation	Estimated Yield	Reported Maximum Yield
	inches		bu/ac	
1982	1.8	9.6	37	44
1983	2.8	7.4	33	31
1984	1.2	3.9	12	10
1985	-	2.9	4	8
1986	0.4	8.1	26	30

Table 6. Comparison of nitrogen fertilizer recommendations for Selles et al. (1988) experiments.

Year	Soil Nitrate-N	Current Recommendations			New Recommendations			Experimental¶	
		Dry	Normal	Wet	75%	50%	25%	New	Max
	lb/ac	lb/ac							
1982	20	45	65	85	25	65	90	115	115
1983	25	40	60	80	20	60	90	95	110
1984	13	50	70	90	35	70	100	0	-16
1985	32	30	50	70	15	50	80	0	92
1986	46	15	35	55	5	35	65	60	131

¶ Rate predicted by the target yield system and maximum rate actually applied.

Table 7. Comparison of target yields using the reported spring soil moisture data to maximum yields reported by Selles et al. (1988) .

Year	25%	50%	75%	Maximum Yield	
inches:	7.0	5.6	4.3	Precipitation	bu/ac
1982	31	24	18	9.6	44
1983	36	29	22	7.4	31
1984	29	22	16	3.9	10
1985	24	18	11	2.9	8
1986	26	19	13	8.1	30

4% and spring moisture had to be guessed, since it was not reported. The parameters for these experiments are described in Table 8. The predicted target yields and N recommended rates can then be compared to those obtained and used, respectively, in the experiment in Table 9.

Table 8. Spring soil moisture, growing season precipitation, target yields and recommended Nitrogen rates for van Kessel and Livingston (1989) experiments.

Treatment	Spring Soil Moisture	May-July Precipitation	Target Yield	Recommended N rate
	inches		bu/ac	lb/ac
Dryland	1.5§	5.2	19	15
Irrigation	1.5	11.0	42	110

§ Assumed values.

Table 9. Rates used and obtained yields by van Kessel and Livingston (1989).

Treatment	Nitrogen Rate Lb/ac	Wheat Yield bu/ac	Current Method of Recommendations Dry	Normal	Wet
Dryland	10	16	5	25	45
	50	18			
	100	20			
Irrigation	10	30		85	
	50	38			
	100	40			

The target yield system predicted very accurately the experimental results obtained by van Kessel and Livingston (1989).

Experiments by Entz and Fowler (1989)

Since the N fertilizer rate in all experiments was 100 kg N ha^{-1}, it was assumed the optimum fertilization conditions were provided in each of the three years of their experiments. The May-July precipitation used in these calculations was taken from historical data of the Rural Municipalities (R.M.), where these experiments were conducted or the nearest R.M. for which climatic data were available. In spite of the broad basis of climatic data the agreement between predicted and actually obtained yields was remarkably good (Table 10).

Experiments by Hultgreen and Morgan (1984)

No climatic data are offered by these authors but the average results over a three year period were used to assess the target yield under typical soil moisture conditions and for 50% probability ("normal") of precipitation. It would appear that the uniformly applied rate of 56 kg N ha^{-1} by the authors was slightly less than the optimum "normal" N fertilization rate (Table 11). Again the similarity in the predicted and actually obtained yields was remarkable.

Table 10. Comparison of targeted and actually obtained yield by Entz and Fowler (1989).

Year	Spring Soil Moisture	May-July Precipitation	Target Yield	Reported Yield
	inches		bu/ac	
		Clair		
1986	1.2	8.6 (337)¶	34	32
1987	1.0	6.8 (336)	26	26
1988	0.7	5.0 (336)	17	15
		Outlook		
1986	0.9	7.8 (254)	24	21
		Watrous		
1986	1.0	7.5 (310)	26	21
		Hagen		
1987	0.8	6.4 (430)	26	27
		Paddockwood		
1987	1.5	7.8 (490)	33	34

¶ Number in brackets denotes R.M. from which climatic data were used for target yields.

Table 11. Comparison of target yields to three year average data by Hultgreen and Morgan (1984).

Parameter	25%	50%	75%
Target Yield, bu/ac	37	30	24
Nitrogen Rate, lb/ac	90	60	30
	Applied Rate 56 kg N ha^{-1}		
	1981	1982	1983
Average Yield, bu/ac	27	27	31

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